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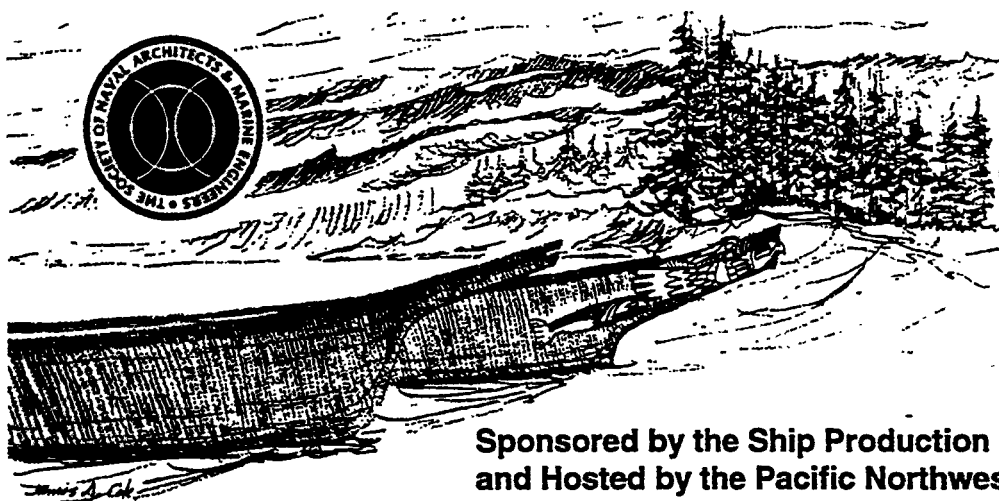
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601 PAVONIA AVENUE, JERSEY CITY, NJ 07306

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**A Comparative Study of U.S. and Foreign Naval Acquisition,
Design and Construction Policy and Practices**

Patrick D. Cahill (AM) and Howard M. Bunch (LFL), University of Michigan Department of
Naval Architecture and Marine Engineering, U.S.A.

ABSTRACT

In an effort to reduce the cost of Navy ships without significantly reducing capability, the U.S. Navy has performed a series of ongoing investigations into areas of potential cost reduction. One of these investigations was a literature study done at the University of Michigan Department of Naval Architecture and Marine Engineering to identify and compare acquisition, design and construction practices in a number of different countries. Recommendations for potential cost saving changes to the U.S. Navy system including reduction of administrative costs, design to cost, and changes in labor policies, were made based on the comparisons. This paper is a modified version of the final report submitted to the Department of the Navy.

INTRODUCTION

The United States Navy operates some of the most sophisticated and technologically advanced ships in the world. In order to perform the primary mission of maintaining U.S. sovereignty as a maritime nation and freedom of the seas, the Navy must be prepared to meet a spectrum of threats from simple to highly advanced anywhere in the world at any time. To ensure that Naval Commanders always have a technological edge over any threat, the Navy has evolved a complex infrastructure for ship design and acquisition. Historically, performance factors have always had precedence over cost factors. However, now and into the foreseeable future, cost is increasingly important.

Rather than reducing the capabilities of its ships, the Navy is interested in reducing costs by adopting more efficient practices in the acquisition, design and construction processes. The perception that there is room for improvement was highlighted by a March 1993 visit by NavSea personnel to Japan, where it was noted that the Japanese IHI shipyard in Tokyo expects to build DD 176 (Hull 2316), the fourth ship of the Kongo class Aegis destroyers, for 2-2.2 million man-hours. This will be the first of the class to be constructed in Tokyo, the first three will be built at MHI

in Nagasaki. (Summers, 1993) This is compared to the construction man-hours on the DDG-51 class, which range from 4.5-5 million man-hours for DDG-51 to 2.5-3 million man-hours on DDG-56, BIW's fourth of the class. The reasons for fewer man-hours in Japan are numerous, including increasing dimensions to allow easier construction access, use of commercial grade equipment, and a different design and construction process. (summers, 1993)

This paper outlines the significant phases in the naval acquisition design and construction process for a number of different countries, and attempts to relate them to the equivalent U.S. Navy phase. Comparisons of time to completion, cost level of detail and end products of each phase were developed using information available in the University of Michigan and NavSea databases. Areas for potential improvement within the U.S. system are also identified.

The major broad areas for improvement detailed in the body of report, are: reduction of administrative costs by the government; adopting a design-to-cost system, using concept design to drive R&D efforts incorporating build strategy and lifecycle cost analysis into early stage design, adopting some basic paradigm shifts in the understanding of the relationships between, cost, dimensions, weight system complexity and producibility; and development of more efficient labor practices within the private shipyards.

**OVERVIEW OF THE NAVAL ACQUISITION,
DESIGN AND CONSTRUCTION PROCESS**

This section provides a brief overview of the process and major organizations involved in each country reviews and includes some nations for which very limited data was available and are therefore not expanded in the body of the report.

US. Navy

The United States Navy uses a phased process in which a design typically matures within the Navy, and budgeting approval is provided through a civilian/military interchange. Designs are primarily government generated through contract design, at which

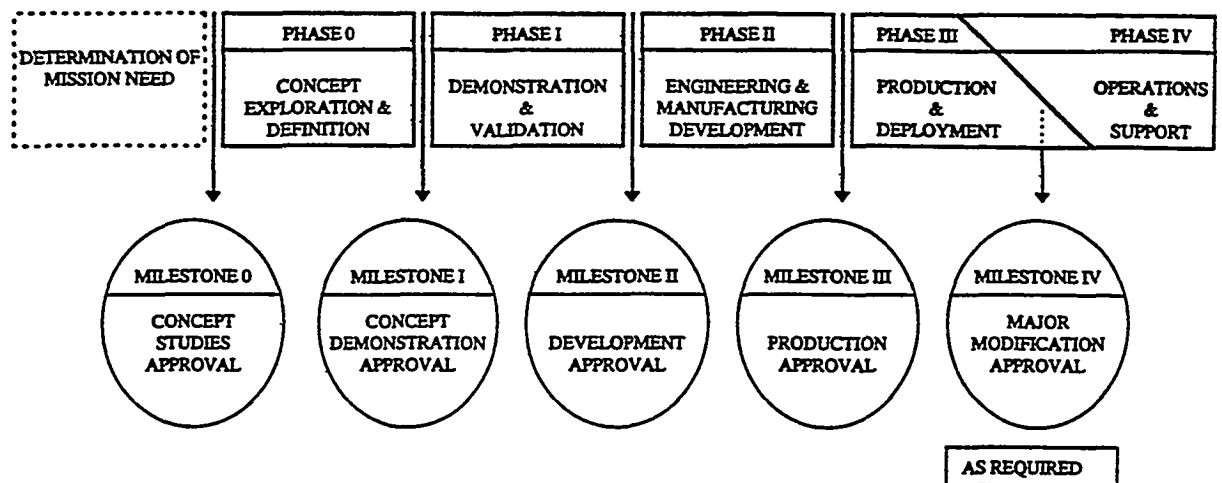


Figure 1 USN Acquisition Process (Ball, 1992)

time bids are taken from private shipyards, who perform both detail design and construction. Government interaction continues throughout construction, and many changes are incorporated as construction progresses. In 1993 the Navy underwent major organizational changes that have impacted the details of the procurement process. The basic process, which is derived from the Department of Defense (DOD) 5000 series instructions, is unchanged and is shown above in Figure 1

Japan

The *Japanese* government uses a phased process similar to the U.S., but with considerably fewer players. Designs are developed through contract design by the government. Construction contracts are generally not competitively bid. Private shipyards perform detailed design and construction with very little government interaction and few changes to the design during construction. **Figure 2** shows the basic process and

EXECUTOR	MARITIME STAFF OFFICE	INTERNAL BUREAU OF THE JAPAN DEFENSE AGENCY	MINISTRY OF FINANCE	DIET
ITEM	REQUEST → (MSO PLAN)	REQUEST → (JDA PLAN)	GOVERNMENT PLAN →	APPROVAL
SCHEDULE	April	August	December	March

Figure 2 Process of Budget Request (JDA, 1993)



Figure 3 Process of Naval Shipbuilding (JDA, 1993)

organizations involved, while Figure 3 lays out the major milestones and the decision making process.

Italy

The entire process is closely controlled within the Navy, and parallels the U.S. process. Contracts are competitively awarded to private shipyards, who do detail design and construction. The Italians may also use government shipyards for construction, rather than strictly private firms. (Craig, 1993)

Germany

The phased process is again similar to the U.S. It is notable that a civilian design firm is brought in early to review the military developed concept and provide feedback as on how well the design concept addresses the requirements. (Abels, 1992)

Korea

Due to the high degree of government involvement

in their commercial ship construction, the military process is believed to be closely government controlled, with the detailed design and construction performed by private yards. (Martin, 1990)

Canada

The Canadian (and NATO) processes are very similar to the U.S. process. A significant difference is the design-t-cost philosophy adopted in the earliest stages of design. Contracts are competed to private yards for detail design and construction. Figure 4 illustrates the Defence Program Management System (DPMS) process, while figure 5 shows the relationship of the process to design progress. (Craig, 1993)

NATO

NATO has a Periodic Armament Procurement System (PAPS) similar to the Canadian's DPMS. The NATO process is shown in Figure 6.

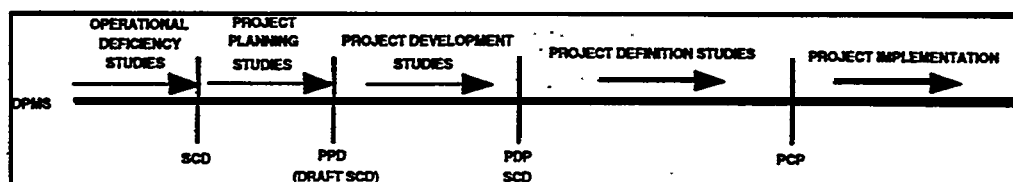


Figure 4 DPMS Process (Craig, 1993)

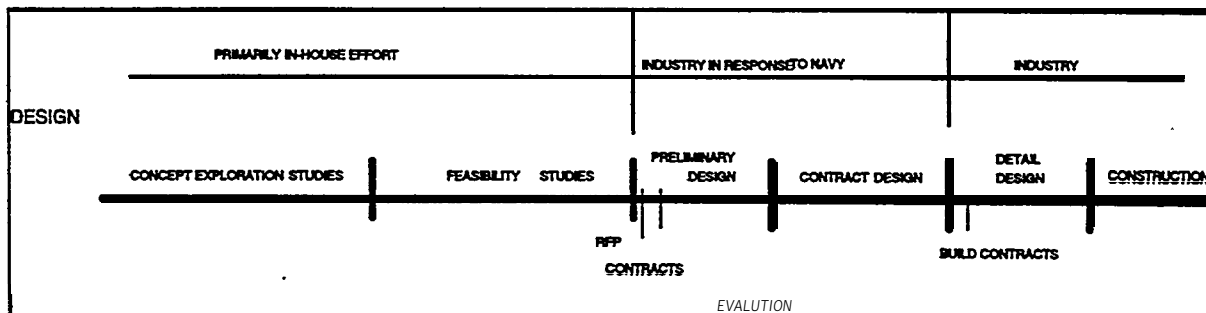


Figure 5 Canadian Design Recess (Craig, 1993)

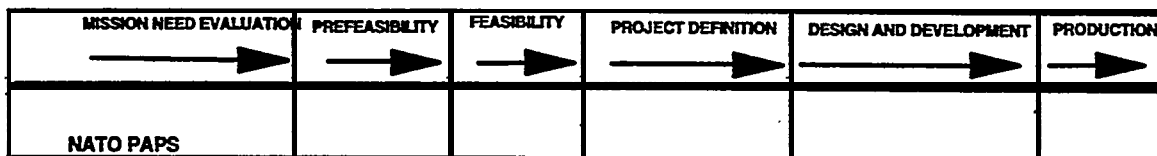


Figure 6 NATO PAPS process (Craig, 1993)

U.K

The British system is also similar to the U.S. process in terms of phases and end products of each phase. Design through to the contract stage is performed primarily by the Navy, with detail design and construction contracted out to private yards. A major difference appears to be in the emphasis on driving research and development efforts from warship design concepts, rather than trying to fit a research and development (R&D) product into a maturing design. This is elaborated on in the following section. (Andrews, 1992)

France

The French process is quite different from the U.S. process in that the government through the Director of Naval Construction, exercises control for the entire life of the project from concept through construction. The detailed design and construction are done by a government shipyard, and there is no competitive bidding involved. (Andrews, 1992)

PROAPPROVAL AND CONCEPT DEVELOPMENT PHASE

U.S. NAVY

The acquisition process currently in effect for major warships is Acquisition Category I-D (ACAT ID), in which the Secretary of Defense is the major milestone decision making authority. The basic flow for the process is shown below in Figure 7.

A brief explanation of the abbreviations used is provided in Table I below. The process starts when it is determined that a capability shortfall exists which generates a need for a new ship. The most common reason for the need is to replace a ship class that is leaving service because of old age, inability to modernize or excessive cost of operations and maintenance. For many years, force levels were held relatively constant which generated the need for replacement. Although force levels are being reduced, replacement is still the number one reason for new ship designs. Other reasons for new ship designs include

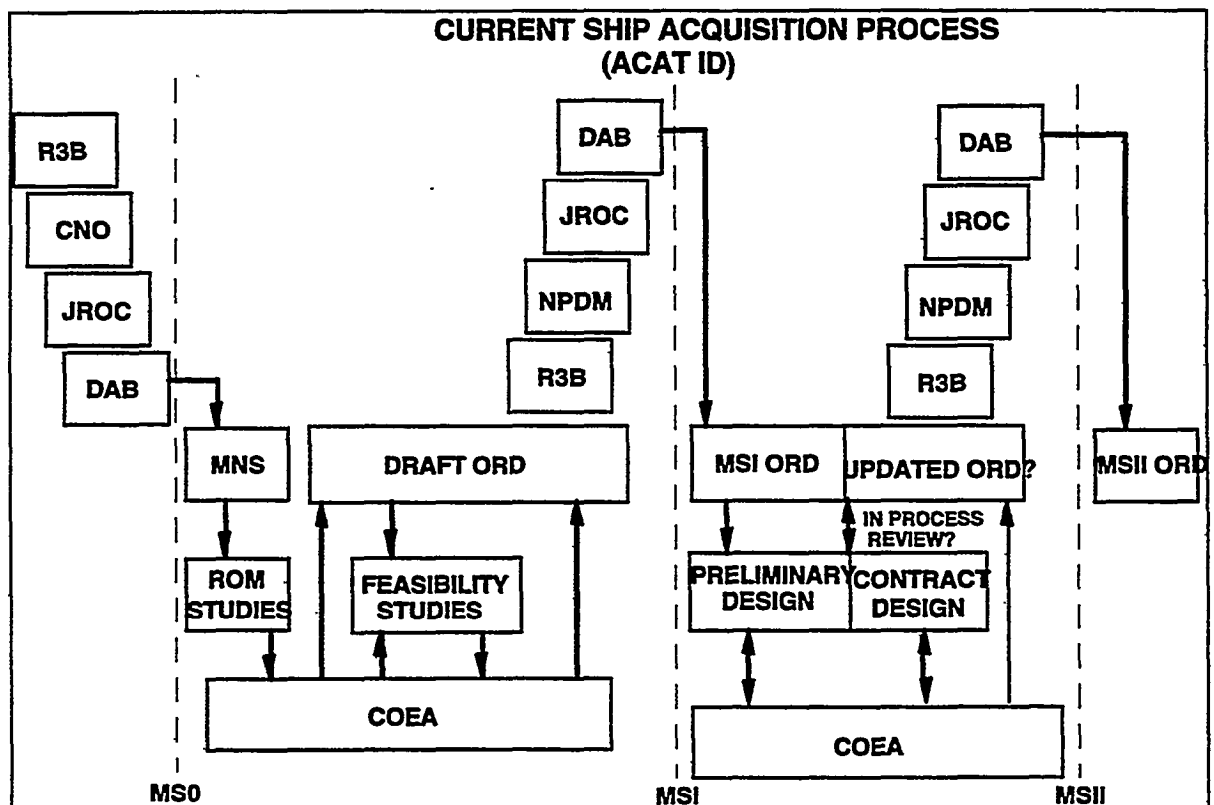


Figure 7 ACAT ID Process

R3B	Resources Review and Requirements Board, Chaired by N8
CNO	Chief of Naval Operations
JROC	Joint Requirements Oversight Council, includes all service vice chiefs and the Assistant Commandant of the Marine Corps
DAB	Defense Acquisition Board chaired by the Undersecretary of Defense (Acquisition)
NPDM	Navy Program Decision meeting
COEA	Cost and Operational Effectiveness Analysis
ORD	Operational Requirements Document
MNS	Mission Need Statement

Table I (Tibbits, 1993)

new threats (Aegis ships in response to new air to surface and cruise missile threats), new or changed missions (the driver behind the development of the mine countermeasures support ship) and new technologies (SWATH and LCAC's). (Tibbits, 1993)

The ACAT ID process formalizes the pre-milestone O decision making, and requires the involvement of a number of different organization. They generate a Mission Need Statement (MNS) which is limited to three pages in length and states the need that must be satisfied, but does not address performance requirements or solutions. The MNS is then forwarded for both Joint Chiefs of Staff (JCS) and DOD approval. After approval, feasibility design studies begin, but the new process adds an iterative cycle of Cost and Operational Effectiveness Analysis (COEA) into the studies at both a Rough Order of Magnitude (ROM) and feasibility design level of detail. The COEA results in the inclusion of performance objectives and thresholds in the Operational Requirements Document (ORD), which has replaced the old Tentative Operational Requirements (TOR) document. In fact, the COEA is now required at every phase of the design process and must be done at each subsequent milestone following milestone O. The entire process up to milestone O can take 1-3 years. (Tibbits, 1993)

Japan

The Central Procurement Office (CPO) is the organization authorized by the Director General of the Japan Defense Agency (JDA) to procure major defense articles and services. (Grossi, 1993) The JDA does not have to undergo the same procurement process as the

U.S. A block funding method is which in which the CPO decides what to buy based on a long term defense plan, and authorizes design development and procurements. The JDA budget is approximately \$30 billion, of which five percent or \$1.5 billion is dedicated to ship construction. This \$1.5 billion annually is budgeted out to provide for the construction of approximately five naval vessels per year two major combatants, one auxiliary, one mine warfare vessel and one submarine. The goal is to maintain a fleet of approximately 60 ships. (Martin 1990)

Italy

The concept development stage is called Phase O in the Italian process The primary inputs. are mission analysis and long term forecasting which define the Long Term ten-year planning. The Plan and Policy (3rd) Department and General Financial Planning Office of the Navy General Staff are the major players in this phase. (Craig, 1993)

Germany

The German Navy determines the operational requirements for a new vessel. This phase is not considered as part of the formal design and construction cycle. (Abels, 1992)

Canada

The Canadian DPMS closely follows the U.S. system in terms of phases of Naval acquisition, design and construction.

The DPMS initial phase is actually broken into two parts, referred to as Operational Deficiency Studies and Project Planning Studies. This phase defines the operational requirements and specific concept alternatives (with costs) to meet the requirements. (Craig, 1993)

NATO

The NATO Periodic Armaments Procurement System (PAPS) also closely follows the U.S. process. The first phase of the NATO PAPS is Concept Exploration Studies. (Craig, 1993)

U.K

The Royal Navy process combines the two phases of concept Studies and Concept Design. Concept Studies are usually commenced ahead of a clear requirement and are closely linked to weapons systems proposals and development commenced sufficiently early, they can be used to identify where research and development efforts should focus. (Andrews, 1992)

Concept Design occurs about 10 years prior to the First of Class In Service Date, and marks the beginning of the approval process for the Staff Target and Staff

Requirement The production of a baseline Concept Design sufficiently defined to be costed with some accuracy is more important than the range of material solutions, since it provides the basis for investigating incremental capability enhancements. It is complemented by Operational Research studies, on either whole ship characteristics or aspects related to major weapon system choices. From these studies, the staff develops the staff target and provides a paper to the Equipment Procurement Committee (EPC), whose agreement is required to commence feasibility. (Andrews, 1992)

The process takes 1-3 years to complete and is performed within the Defence department. Multi-level departmental endorsements are required throughout the Ministry Of Defence. The papers are continually updated and revised, as special interests are allowed to suggest and add features to the ship concept. (Andrews, 1992)

Comparison

The U.S. process is very involved, and requires the participation of a number of different organizations and individuals. However, many of the other countries reviewed use a similar process. The most notable exception is the Japanese block funding process, which eliminates several iterations of the acquisition cycle.

The complexity of the pre-approval process may have the positive effect of exercising greater control over Naval acquisition by ensuring a well developed set of requirements, but adds time and, therefore, cost to the process. Longer term, dedicated budgets, such as used by the Japanese, may help eliminate some of the "red tape" in the U.S. process. However, a long term budgeting process has the downside of limited flexibility in responding to changing requirements.

Additionally, the U.K process of closely linking ship concept development to systems R&D would appear to be a cost effective practice, providing distinct and specific guidance to R&D efforts, which then reduce later design costs as a more mature system or concept is placed on the ship.

FEASIBILITY STUDIES

U.S. Navy

Feasibility studies begin at Milestone O, and are performed by teams of 3-20 dedicated engineers, with additional technical and subcontracting support brought in as needed. The primary purpose of a feasibility study is to produce cost schedule and performance alternatives to help the ultimate customer (CNO) decide what he will buy. If the cost estimate is to be credible, the feasibility study team (typically less than a half

dozen design engineers working for several weeks to several months) must produce a ship design which accurately predicts what the ship will look like at the end of contract design 18-36 months later. This requires an intimate knowledge of the myriad of NavSea design practices and standards and the NavSea/DTRC developed computer synthesis models. Engineers with such experience are rare (even in the Navy), which is the major reason why correcting out early stage design is fraught with risk. There are, however, instances where the design workload is such that additional resources are needed, and a few feasibility studies are contracted to selected naval architecture firms. (Tibbbs, 1988)

The primary objectives of feasibility studies are to:

- Determine cost and performance alternatives that allow the decision makers to assess cost versus capability,

- Identify feasible solutions,

- Address major technical risks, and

- Provide class F cost estimate (not of budget quality).

A feasible design must meet four criteria; it must meet the need, be affordable from a Ship Construction New (SCN) standpoint, be technically executable from an engineering standpoint, and be politically acceptable. The final package of a feasibility study is a set of drawings, sketches and documents that contain a:

- Description of the ship geometry;

- Definition of all mission critical subsystems;

- Definition of areas and volumes in a general arrangement drawing and

- Single digit weight estimate by Ship Work Breakdown Structure (SWBS), which is the primary input to cost estimates.

Feasibility studies can be accomplished in 316 months. However, the review process and COEA can add another six months to the process. (Tibbbs, 1993)

During this phase the NavSea Shipbuilding Support Office (NAVSHIPSO) provides Advanced Planning Studies (APS) to the Ship Acquisition Program Manager (SHAPM), which provides estimates of required contract and construction periods, manning level requirements and production need requirements of principal long lead components and controlling items. (Ennis, 1991).

Japan

In Japan the feasibility study phase takes approximately 2 years. Included are combat system integration studies, arrangement studies, support systems studies, electric plant and damage control studies. The time and cost to complete the process is difficult to determine, as the Japanese actually

Performed pre-studies of the DDG-51 and built mock-ups of the SPY-1D array for the DD 173 beginning three years prior to budget approval. (Summers, 1993) Further research would be required to determine if other Japanese naval construction programs also used a pre-study pm.

Italy

The feasibility phase is called Phase 1 in the Italian process. The goal is to produce the staff requirement. In this phase a rough operational requirement is generated by the planning and policy department for the requirements department. The requirements department is composed of approximately 40 operational officers from the various combat areas (Weapons, Communications, Command and Control Systems, ASW, etc.), Engine Plants and Platform officers. This department is responsible for the refinement of the operational requirement which is then forwarded to the "design committee", MARICONAVARMI and to the procurement agency, the General Directorate for Shipbuilding and Naval weapons systems, NAVALCOSTARMI. MARICONAVARMI is tasked to provide technical support to the Navy General Staff, and conducts a feasibility study based on the operational requirement. NAVALCOSTARMI develops a first estimation of costs. After a final review, which includes cost capability trade off analysis, the Operational Requirement is endorsed at the General Staff level and used as the basis for Phase 2. (Craig, 1993)

Germany

Feasibility studies are called the Pre-Concept phase in the German design process. It involves the Navy definition of requirements and a private design firm's analysis of those requirements towards the development of a design. The end product of this phase is called the tactical requirement. (Abels, 1992)

Canada

In the DPMS this phase is referred to as Project Development Studies. The objective is to develop the technical baseline of the design and provide a level of detail sufficient for a preliminary cost estimate, which is the basis for a design to cost target. This phase determines the "maximums" for a design. All subsequent phases, in theory, only reduce size, weight and cost. (Craig, 1993)

NATO

This phase is broken into two parts in the PAPS: Preliminary and Feasibility. The goals, objectives and outcomes are the same as in the Canadian system. (Craig, 1993)

U K

This phase is also referred to as Feasibility Studies in the Royal Navy. They are conducted by a full pledged Project team under the leadership of a Warship Project Manager, which is similar to the U.S. SHAPM. These studies provide the technical justification behind submission to the Equipment Procurement Committee of the more substantial Staff Requirement. They also explore the viability of the requirement and provide a clear cost. This is followed by Ministerial approval for expenditure of the next phase. (Andrews, 1992)

Subcontracting to industry and design firms is occasionally undertaken during feasibility studies. This phase typically lasts 1-2 years and requires at least 30 man years of effort. (Andrews, 1992)

Comparison

Information available shows that the feasibility study process is approximately the same in all countries reviewed, with roughly the same end product; a tactical requirement that defines the basic parameters of the ship. It is interesting to note that in the Canadian and NATO systems the resultant design is considered to be a maximum and provides the basis for design-to-cost limits. This may be a good model for the U.S. to follow, as it determines at a very early stage what capability can be purchased for a given budget and drives all later design parameters.

Although specific cost information for comparison is not available, it is apparent that the Japanese system of performing pre-studies and other design activities prior to budget approval for a specific vessel may result in the appearance of a less expensive design process.

It is also notable that the Germans bring a civilian firm into the process very early to determine whether or not the Navy developed design is actually feasible and meets the desired requirements.. This may be of use to the U.S. Navy, as many of the design firms in Washington are filled with former military personnel with considerable experience that could be applied in an early stage design review.

PRELIMINARY DESIGN AND CONTRACT DESIGN

U.S. Navy

preliminary design starts at Milestone 1 and includes preliminary hull, mechanical and electrical (HM&E) design, combat systems integration worth and continued program documentation development by the SHAPM. (NavSea 1990)

During this stage, firm "design to" requirements, budgets and constraints are established. Numerous

tradeoffs are conducted at the subsystem and component levels, and synergistic combinations are sought. Preliminary design is much more labor intensive than feasibility studies (several hundred engineers working for a minimum of six months) and considerable numbers of individual tasks are contracted out (Tibbits, 1988)

The trend towards increasing reliance on contractor support continues. For the more typical design where the Navy retains firm hands-on control, more and more tasks are being contracted-out by individual technical codes. A 1982 ship design study acknowledged this to be a permanent way of life and recommended various steps be taken to improve the process. As a result long-term contracts were competitively awarded to a pair of contractors for whole ship design support. Pairs of contracts were also awarded in support of each major engineering group and subgroup. (Tibbits, 1988)

During this phase of recent Naval designs the Navy has also involved shipbuilders as a group. The shipbuilders have generally only provided producibility recommendations, which has been expanded in recent designs to include preliminary build strategies.

At the end of the preliminary design stage a cost estimate is developed which is based on the parameters defined by the design. The primary parameters are weight and dimensions, which are used as inputs to the Navy's computerized cost estimating models. Producibility is not accounted for in the cost models developed by NavSea with the result that complexity and system density can eventually add to the original estimated cost.

To change the ship costing models so that each specific volume type would have its own systems cost (tanks cheap, electronics costly in terms of supporting systems) and so that **deck height reductions would raise rather lower costs would require major investments in time and money.** (Sims, 1991) This is an area that the Navy is currently working to improve.

The entire process lasts 6 months to a year. and, prior to the ACAT ID process, resulted in the Top Level Requirements, which is the minimum specifications. It includes a hullform and preliminary definition of all HM&E and Combat Systems components necessary to meet the TLR. Specifically, the preliminary design includes

- More detailed ship geometry;
- Three digit SWBS weight estimate which allows generation of a Class C, or budget quality cost estimated
- **Ships lines** and arrangements drawings;
- Master Equipment List (MEL);
- Intact and damaged stability analysis; and
- Combat system baseline.

Japan

It is during the preliminary design phase that one of the major differences in the Japanese process, the use of concurrent design becomes apparent. Concurrent design is a highly leveraged concept and associated body of practice to simultaneously design a product and its associated life cycle processes. For the Defense Industrial base it holds the potential for producing products that better satisfy end user needs and substantially reduce acquisition cost and development time. It can also ensure the availability of appropriate manufacturing means for manufacture of advanced weapon systems, and replace inefficient sequential design practices which prematurely narrow design options. Concurrent design results in streamlined practices in which non-value added labor is reduced more design options are kept open longer, and issues of performance, Producibility, supportability, quality and cost are simultaneously considered and traded off from the earliest phases of design. (Martin, 1990)

The preliminary design stage for the DD 173 lasted approximately 6 months. (Summers, 1993)

Italy

This phase, called Phase 2, details the Technical-Operational requirements of the project. It involves iterations through the General Staff, MARICONAVARMI and NAVALCOSTARML. The output of the phase is a General Rejection Document that covers all aspects of the design, including life cycle costs, and is submitted to the Chief of Naval Staff for approval. (Craig, 1993)

Germany

Called Concept Phase in German design. It includes a complete preliminary design, selection of all major components, and start of support planning by the design agent. The construction yard begins build strategy development and cost estimating. The Navy shifts to an approval role during this phase. (Abels, 1992)

The end product of this phase is called the Military-Technical Objective, similar to the TLR or ORD.

Canada

This phase is referred to as Project Definition Studies in the DPMS. It actually encompasses the equivalent of preliminary and contract design in the U.S. process. The objective is to provide a functional baseline for the detailed design, with functional descriptions of all systems and their integration. Specific design characteristics are also identified and written into the specifications, such as noise, EMI, shock and other requirements. (Craig, 1993)

NATO

Also referred to as Project Definition, but does not include the contract design phase. The objectives are similar to the DPMS, but does not include detail enough for writing specifications. (Craig, 1993)

U.K

This phase is referred to as Design Definition in the U.K and involves both preliminary design and contract design. The design is expanded from several options, each having a general arrangement and roughly 10 critical system drawings, to a single option, the ship definition, encompassing over 200 contract guidance drawings. (Andrews, 1992)

The effort requires 1-3 years to complete. (Andrews, 1992)

Comparison

Again the phase and its objectives are similar for all nations reviewed. However, two major activities begin in other countries that did not formerly occur in the U.S. process. These are the development of life cycle costs and the beginning of a build strategy. Both of these activities, occurring during preliminary design, will have the effect of reducing costs during detail design and construction. Part of life cycle cost development is the definition of logistic support requirements, which, in order to reduce costs over the entire fleet, dictate commonality in systems and components. The development of a build strategy during this early phase results in producibility driven design concepts being incorporated into the next phase, contract design. The LPD-17 design will be the first major naval vessel to be designed under the ACAT ID process, which incorporates the COEA. This new process should address many of the concurrent engineering deficiencies in the U.S. Navy.

CONTRACT DESIGN

U.S. Navy

In the former acquisition system the preliminary design package went into contract design following another Ship Characteristics Improvement Board (SCIB) review, with the same organizations playing key roles. In the new System, there is no milestone separating preliminary and contract design. In contract design the size of the team is doubled, and an effort of about one year commences. (Tibbits, 1993)

Participation in contract design has varied over several U.S. Navy programs. In the DDG-51 design the Navy retained contract design in-house, but selected three shipbuilders to participate in the design. In the

SSN-21 design, the contract design was contracted out to the two shipbuilders, who had both participated in preliminary design. The LHD and LSIM1 contract designs were also contracted out to shipbuilders. (Tibbits, 1988)

The end of contract design results in a package of contract drawings, contract guidance drawings, Project Peculiar Documents (PPD's) and specifications of sufficient level of detail to allow a shipbuilder to develop a bid. These generally include ship's lines drawing, combat systems space and wiring arrangement drawings, main and auxiliary machinery space and system arrangement drawings and detailed specifications. (NavSea 1990) In addition, Government Furnished information and material (GFI and GFM) schedules are developed, the Contract Data Requirements List (CDRL) is generated, the HVAC manual is written and an electric load analysis is performed. (Tibbits, 1993)

Cost Modeling. Contract design is the point at which weight dimensions and acquisition cost estimates are frozen. Decisions made up to this point have a lasting impact on the acquisition cost of a ship class. The DDG-51 lead ship cost was severely impacted by decisions made up to and including the contract design stage, as evidenced by the number and scope of Engineering Change Proposals (ECP's) and Field Modification requests (FMR's) incorporated into the design during construction.

The most significant of these decisions was relating cost directly to weight, ignoring the producibility cost impacts of compressing systems and equipment into a smaller volume. The DDG-51 design team was under extreme pressure to reduce cost. Because of the perceived relationship between cost and weight the beam was reduced by 2 feet under direct orders from the Secretary of the Navy (SecNav), and the clean ballast fuel system was replaced by a more complex and expensive compensated fuel system. The U.S. Navy is slowly learning that low cost and ease of construction are often inversely related to dimensions and weight. (Sims, 1991)

Contract vs. Guidance Documentation. The U.S. Navy has historically issued contract versus guidance drawings for a number of systems and spaces. The difference is that the locations and arrangements defined in the contract drawings are legally binding to the shipbuilder, and can only be changed through a formal change process. On the other hand contract guidance drawings provide a recommendation for locations and arrangements, and the shipbuilder is given latitude to make minor changes in order to accommodate production efficiency.

Preparation of specifications. Detailed specifications are written by individual NavSea technical codes and compiled by the SHAPM. Literally hundreds of personnel are involved in the development of a set of ship's specifications. The General Specifications (Gen Specs) are used as a baseline, and modified to suit the changes incorporated by the individual whicrd codes. The technical codes do not always coordinate their specific changes with each other, resulting in a specifications package with a considerable number of conflicts, which results in confusion and changes in the shipyard. (Ball, 1992)

It should be noted that the design practices of the U.S. are more thoroughly documented than those of other nations. (Tibbits, 1988)

Japan

The Japanese equivalent of Contract Design takes approximately 6 months. However, it differs in its intensity and need for detail because contracts are not competed in the Japanese system. (Summers, 1993) It is performed by government designers who are employed by Defence Ship Design Department (Grossi, 1993)

It is apparent that in the Kongo design, the Japanese, with the help of engineers who worked on the DDG-51 design have learned from the mistakes made on the DDG-51 class. The U.S. Navy sent a Naval Architect to Japan, who assisted in designing a ship with an optimized size to displacement ratio. This resulted in a design with increased overall dimensions and deck heights in order, to avoid the construction congestion problems experienced on the Arleigh Burke. (Sims, 1991)

Italy

Phase 3 is similar to contract design, during which NAVALCOSTARMI develops and issues the technical specifications. (Craig, 1993)

Germany

Called Definition Phase in German naval design. It includes development of a 1:5 scale basic model and the specification package. Navy preliminary approval of the specification occurs during this phase. The shipyard will begin contract negotiations at the end of the phase. (Abels, 1992)

Canada

The contract design phase is incorporated into the Project Definition Studies phase. The contractual package is similar to the U.S., with a set of

specifications and contract drawings developed. (Craig 1993)

NATO

The contract design stage is incorporated a phase called Design and development which includes the beginning of Detailed Design. The final product is a contractual baseline and a level of definition adequate for a Class B cost estimate, which is the design-to estimate. (Craig, 1993)

U.K

Contract design is incorporated into the Design Definition phase. It should be noted that guidance rather than contract drawings are developed. (Andrews, 1992)

Comparison

Contract design is very similar in most of the nations reviewed. The level of detail generated by the U.S. Navy and some other countries is much greater than that developed in Japan. This is directly related to competition for contracts. The only other notable difference is the German development of a 1:5 scale model during contract design which the U.S. Navy is beginning to do through three dimensional "virtual CAD models.

PRE-AWARD PHASE

U.S. Navy

The pre-award phase begins at Milestone 2, following Defense Acquisition Board (DAB) approval of the contract design. This phase involves development of the Request for Proposals (RET) by the SHAPM. The RFP is the compilation of the contract design, specifications and Contract Requirements Documentation List (CDRL). (Tibbits, 1993) The RFP is presented to DoD, and then released to the shipbuilders for bids. During this phase the shipbuilders develop a build strategy to support their bid, and are provided an opportunity to request clarification of the REP. The end of this phase results in a contract award, and the start of detail design. The total time for this phase is approximately one year. (NavSea 1990)

Competition and Multi-sourcing vs. Non-Competitive Awards. The US Congress requires that the Navy compete the award of new construction contracts between at least two shipbuilders. However, competition continues to be a gray area. Newport News

is the only shipyard capable of building nuclear aircraft carriers, while Newport News and Electric Boat Groton are the only private yards capable of building nuclear submarines. Public yards, such as Portsmouth, N.H., have essentially been dropped out of the equation. Aegis ship construction is currently restricted between two Aegis qualified yards, Bath Iron Works and Ingalls. The conclusion that can be drawn is that although competition occurs, it is restricted competition, and multi-sourcing often means dual sourcing.

Japan

The time for the pre-award phase is approximately 8 months. The shipbuilding contracts are not competitively bid. (Summers, 1993)

Italy

This is Phase 4, during which NAVALCOSTARMI activates the administrative procedures, including the choice of contractual procedures. The Phase ends with the signing of contracts. (Craig, 1993)

U.K

Requires approximately 1 year for contract negotiations to be completed. (Andrews, 1992)

Comparison

It is during this stage that build strategies are developed within the shipyards and used to support a bid. The contract package has already been developed and changes to suit production methods are difficult to incorporate. The result is that the shipyard must develop a build strategy to suit the design, rather than bid on a design that has already incorporated a logical build strategy.

DETAIL DESIGN

U.S. Navy

Detail design begins at the winning shipyard as soon as a contract is awarded. The initial phases of detail design include procurement of government furnished equipment (GFE) by the government, integration of combat systems software, production planning, structural design and systems design. Detail design overlaps with construction, and is normally about one year ahead of construction. (NavSea 1990)

The total time for detail design is approximately 2 years. (Tibbits, 1993)

The detailed design of the DDG-51 required the services of over 2000 engineers and designers from Bath Iron Works and Gibbs and Cox.

Navy participation continues into the detail design phase. Today, ship design teams continue in being, albeit at reduced levels, past the completion of the contract design phase for all combatant ships and selected auxiliaries and amphibious ships. There is active participation at design reviews with the shipbuilder during the detail design and construction phase. In addition there is a heavy workload associated with the review or approval of shipbuilder drawings, purchase orders, design studies and other key technical documents. (Tibbits, 1988)

Level of Detail Detail design of modern Naval ships includes production design and engineering. Modern Naval design incorporates zone design to allow for group technology construction. Composite drawings that incorporate all structure, equipment and systems within in a zone are developed for interference checking. In the past the composites have been two dimensional overlays, with a separate overlay for each design discipline and major system group. Recent designs have incorporated three dimensional computer generated models, which have greatly enhanced the accuracy of design. In addition to the composites, separate system and arrangements drawings are developed for each system and equipment group (arranged by product Work Breakdown structure (PWBS)). From these detailed zone drawings a series of production drawings that details the fabrication of piece-parts are developed and provided to the production workers. In addition to the drawings, a computerized parts and inventory list is developed. Finally, a detailed production plan, specifying time, order and location of all components is prepared.

In the U.S., very few full scale mock-ups are built as construction aids, something that was emphasized in the Japanese Aegis destroyer program.

Part of detail design is the development of documentation to fulfill the CDRL'S or Contract Drawing Requirements Listt which are the portions of the detail design submitted to the Navy for review and/or approval. Table II is a list of typical detail design documents generated by the shipbuilder and reviewed by NavSea.

Change Order Process. The US Navy has historically relied on the change order process to correct design deficiencies, incorporate in-process shipbuilder recommendations for improvement and incorporate system and equipment updates and improvements. Modern Naval construction requires a shipyard to have an entire division of engineers and designers dedicated to the Engineering Change Proposal (ECP) process.

A.	Purchase Specifications
B.	Technical Manuals
C.	Equipment Drawings
D.	Test Plans and reports
E.	Construction Drawings
F.	Shock/Vibration Reports
G.	Diagrammatic Drawings
H.	Arrangement Drawings
I.	Propeller Data
J.	Structures drawings
K.	Compartment access Drawings
L.	Interface Control Drawings
M.	Calculations and Analyses
N.	Noise Reports
O.	Maintenance manuals
P.	Quarterly Weight Reports
Q.	System Safety Program Plans
R.	EMI Plan and Report
S.	Configuration Management Plan
T.	Inspection Plans
U.	System Descriptions

Table II Typical CDRL List (Tibbits, 1988)

Use of CAD and CAM. The use of CAD and CAM in U.S. Naval design and construction has been limited but is dramatically increasing. CAD was in limited use as a drafting aid on the FFG-7, DD-963 and CG-47 classes. The DDG-51 was bid as an all CAD design, however the technology and training was not in place to make it a reality. The final DDG-51 design was less than 20 percent CAD; however models continue to be developed and the flight upgrade designs are increasingly digitized. The new LPD-17 maybe the first true all CAD surface ship design for the U.S. Navy.

Personnel Training impacts. Designers are generally not trained in production methods. Formal time spent in a shipyard production area is not required. (Bruce, 1988) This is particularly true of the subcontracted designers who work for shipyard-hired design firms.

Japan

Detail design can begin under the Japanese system prior to a contract award. (Summers, 1993) This is a contributor to the cost savings perceived in the Aegis destroyer comparison.

The total time for detail design is about three years. For the Kongo it actually started 21 months before contract award. Sixty personnel from Maritime Maritech assisted MHI in the design. MHI has used between 200 and 500 designers on the DD 173 project. (Martin, 1990)

Use of CAD and CAM. The Japanese are using CAD for a fraction (50 percent to 60 percent) of the design of DDG-2313 because the effort is too expensive and the geometry is too complex. (Martin, 1990)

Personnel Training Impacts, Designers are required to spend time in production area as a part of their formal training. (Bruce, 1988) It is of particular interest that in some cases the designers are also trained as installers. After developing the design details, the technician moves from the drawing room to the assembly building or ways, where he performs the installation of his design. (Summers, 1993)

Italy

Phase 5 of the Italian Navy process encompasses all of the design and construction activities, including final operational evaluation and vessel acceptance (Craig, 1993)

Canada

Called the Reject Implementation Phase in the DPMS. It is similar to the U.S. process, in that the shipyard that wins the construction contract develops the detailed design with the assistance of subcontracted design firms.

NATO

Detail Design is part of the Design and Development phase leading up to construction.

U.K

Requires 3-6 years for combined detailed design and construction. Detail design is undertaken by the shipyard that is awarded the contract.

Comparison

In most countries the winning shipyard performs the detailed design. It appears, however, that the degree of control and oversight resulting in extensive documentation reviews, is much greater in the U.S. than elsewhere. It is also apparent that training designers in production methods and using standard design details, as is done in Japan, can help reduce design costs.

Estimated Cost. Some design cost estimates are provided in the Table III for comparison

Country	ship	Design man-hours
U.S.	DDG-51	6,000,000
Japan	DD-173	1,200,000
U.S.	DD-963	5,000,000
U.S.	CG-47	3,000,000

Table III Design Cost Comparison (Martin, 1990)

Several points are significant in reviewing this table. The CG-47 design utilized the exact hullform and main machinery of the DD-963, but had major system and superstructure changes. The result was a reduction in total detail design required. The DD-173 design closely follows the DDG-51 design, including hullform, systems and superstructure, allowing the Japanese to essentially copy the U.S. design in many cases. The DDG-51 design incorporated a number of features never before designed into Navy ships, and was geometrically and volumetrically constrained by cost, resulting in an extremely complex design with numerous interference issues.

CONSTRUCTION

Limited quantified data was available for countries other than Japan and the U.S. on actual construction programs. However, the current major construction programs of destroyer or frigate type ships that could be used for a more detailed comparison are included.

U.S.

It takes at least 3 years to build a major Naval vessel in the U.S. (Tibbits, 1993)

Subcontracting. Subcontracting of specific parts of the design is very limited in the U.S. In fact, it is primarily restricted to component vendors who provide system components that cannot be efficiently manufactured within the shipyard.

Training and Skill Level of Personnel In most of the shipyards that build major Naval vessels, the production workers are unionized. Cross training has been virtually non-existent however recent labor agreements are changing that. This contributes to some degree to the greater number of man-hours required to

build a ship in the U.S., as it takes several personnel to perform a single task or complete a work unit.

Current Building Program. The DDG-51 Arleigh Burke Class Aegis destroyers comprise the primary Naval construction program currently underway in the U.S. The two shipbuilders are Bath Iron Works Corporation and Ingalls Shipbuilding

Japan

In Japan it also takes about three years to construct a major naval combatant such as the Kongo. (Janes, 1992-93)

Subcontracting. KHI-Kobe subcontract activities include scaffold erection, tack weld assembly, finish welding, piping and sheet metal outfitting, painting, accommodations carpentry and joinery, and insulation work. (Bunch, 1987)

Training and Skill Level of Personnel The Japanese cross train and utilize all yard personnel. (Martin, 1990) It has been noted that flexible, or cross trained, workers were a major factor in the lower man-hours to build the Kongo. (Sims, 1991)

Current Building Program The Japanese have two surface combatant building programs. The most expensive, and most visible, is their version of the Aegis destroyer, the Kongo class. One has been commissioned and three more are under construction

The second program is the Takao Class destroyer, which is an enlarged version of the Asagiri class, of which eight ships were built in the late 1980's. This ship does not incorporate significant stealth or Aegis technology.

Italy

The major Italian program is the 5400 ton D-560" Animoso class, of which two have been built and two more are planned. (Janes, 1992-93)

Germany

The Germans are currently in the beginning of a program to build four Type 123 MEKO frigates, displacing about 4490 tons. (Janes, 1992-93)

Canada

The Canadians are well into the construction of 12 Halifax class 5235 ton frigates. (Janes, 1992-93)

U.K

The Royal Navy is working on the planned acquisition of as many as 23 Duke Class Type 23 frigates, displacing 4200 tons. (Janes, 1992-93)

country	Ship Type	Approximate Tonnage (Full load)	Keel to Commissioning	Man-hours to Completion
U.S	DDG-51	8315 (Janes 1992)	30 mos (Janes, 1992-93)	-5,000,000 mhrs
U.S.	FFG-7	3500 (Janes, 1992)	30 mos (Sanes, 1992-93)	2500,000 mhrs (Martin, 1990)
Japan	13D-173	9485 (Janes, 1992)	34 mos (Janes, 1992-93)	2,036,400 mhrs (Summers, 1993)
Japan	13D-158	4500 (Janes, 1992)	29 mos (Jams, 1992-93)	1,000,000 mhrs (Martin, 1990)
Italy	D-560	5400 (Janes, 1992)	42 mos (Janes, 1992-93)	
Germany	F-215	4490 (Janes, 1992)	38 mos (Janes, 1992-93)	
Canada	FFH-330	-5235 (Janes, 1992)	51 mos (Janes, 1992-93)	2,100,000 mhrs (Martin, 1990)
Canada	13DG-280	5100 (Janes, 1992)	42 mos (Janes, 1992-93)	2,300,000 mhrs (Martin, 1990)
UK	F-230	4200 (Janes, 1992)	54 mos (Janes, 1992-93)	

Table IV Statistics Comparison

Comparison

Constriction Time. The available documentation indicates that the overall time for construction is about the same in Japan, as it is in the U.S. for a similar combatant vessel. (Wines, 1992-93)

Comparison of Acquisition Statistics Table IV firm shows a comparison of estimates found in the literature of costs, man-hours to completion and time from keel laying to delivery.

CONCLUSIONS AND RECOMMENDATIONS

The U.S. Naval acquisition, design and construction process has been closely modeled by many other nations, and NATO. It follows an inherently logical path, and has checks and balances built into it. However, there are things that occur in other countries that, should the U.S. emulate their process, may result in overall cost reductions for naval ships. Based on a qualitative "analysis of foreign policies and practices, the following recommendations have been compiled from the Phase by Phase comparisons.

- . Review the early stage process and look for duplications of effort or unnecessary reviews. Develop a defense budgeting system that is longer term, and dedicate a budget for design and construction that suits a predetermined fleet size and make-up. However, flexibility must be retained in order to counter changes in the thlmat.

- . Use a portion of R&D funding to target specific ship and system designs, rather than developing a ship design and looking for R&D products that could be incorporated into it, or developing products and trying

to fit them into a ship. The Japanese are doing it and it saves money in the later stages of design.

- . Establish design-to-cost maximums at the feasibility or concept design stage. Later design phases are then allowed to reduce, but never increase, cost.

- . Consider the use of a selected civilian design or firms to review the Navy design at the feasibility study level and validate the design to cost and design to requirement features of the ship.

- . Develop build strategies during preliminary design. This will bring producibility into play very early in the design cycle, before it becomes cost prohibitive to make producibility driven changes.

- 1 Incorporate life cycle cost decisions into the preliminary design stage. This will dictate commonality, help prevent "gold plating" and have the *eventual* effect of developing a fleet that is cheaper and easier to maintain and operate

- . Change the contract design practices and be consistent. Either use contract drawings that are developed with build strategy, producibility and life cycle costs incorporated, or give the shipbuilder guidance drawings. Coordinate the development and integration of specifications through a *central* function.

- . If competition must be used, then perform pre-bid qualifications at the preliminary design stage so that a build strategy can be incorporated into the contract drawings that is suitable for the qualified yards. Release the RFP only *to the* prequalified shipyards. This will more closely resemble the system that the Japanese are successfully using.

- . Something that was not noted in the Phase comparisons, but came to light in the literature, is that the time frame for a ship development from concept to

service is generally in excess of ten years. However, the longevity of both the military and civilian personnel who participate in the design development is only about three to four years before moving on to another command, organization or project. Assignment of long-term program managers may add consistency to decisions and have a positive effect on the overall cost of project.

- Encourage shipyards to train designers in production efficient design methods and use standard details.

- 1 Provide the means to establish a greater degree of cross training in the production workforce.

- Reduce the level of in-process change that is input to a design. Frozen designs are less expensive than fluid designs.

- 1 In order to establish a meaningful benchmark cost and schedule data should be requested on each of the cited ongoing construction programs and normalized to account for process and financing differences.

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